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1. Your reference — P1345

2. Patent application number *(The Patent Office will fill in this part)* — 08 JAN 2003 — 0300352.2

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

THE SECRETARY OF STATE FOR DEFENCE
DSTL
Porton Down
Salisbury. Wiltshire. SP4 0JQ

Patents ADP number *(if you know it)* 06997670005

If the applicant is a corporate body, give the country/state of its incorporation — GB

4. Title of the invention — Radio Signal Direction Finder

5. Name of your agent *(if you have one)* — Beckham Robert William

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

D/IPR Formalities Section
Poplar 2
MoD Abbey Wood #2218
Bristol
BS34 8JH. UK

Patents ADP number *(if you know it)* 08534588001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Piority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number or earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body. See note (d))

Yes

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Continuation sheets of this form	
Description	4
Claim*(s)*	2
Abstract	1
Drawing*(s)*	1 + 1

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	Yes (1)
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I / We request the grant of a patent on the basis of this application.

Signature Dr N A Riddle   Date 07 January 2003

12. Name and daytime telephone number of person to contact in the United Kingdom   Miss Laura Morrison   0117 91 30228

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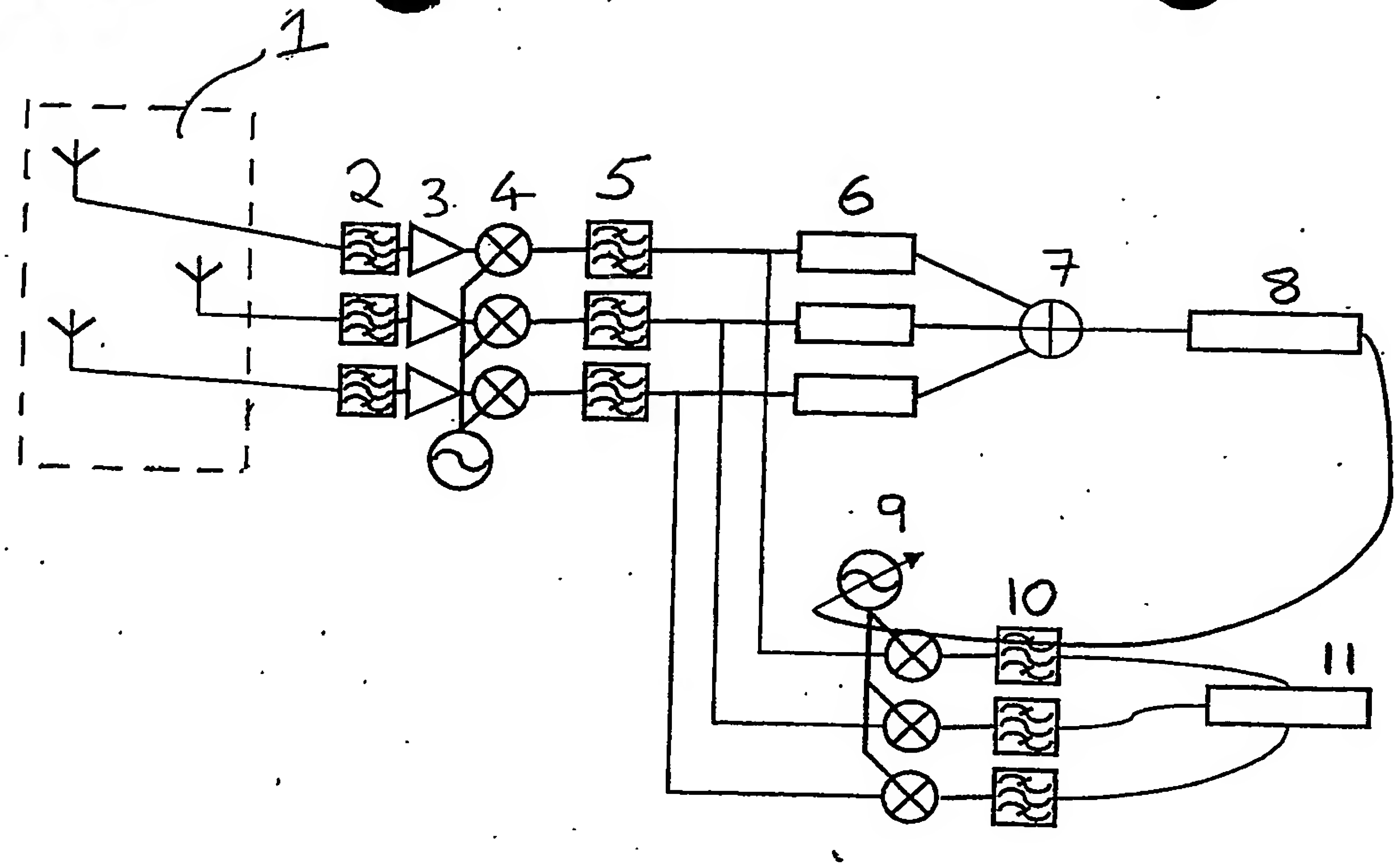

Figure 1

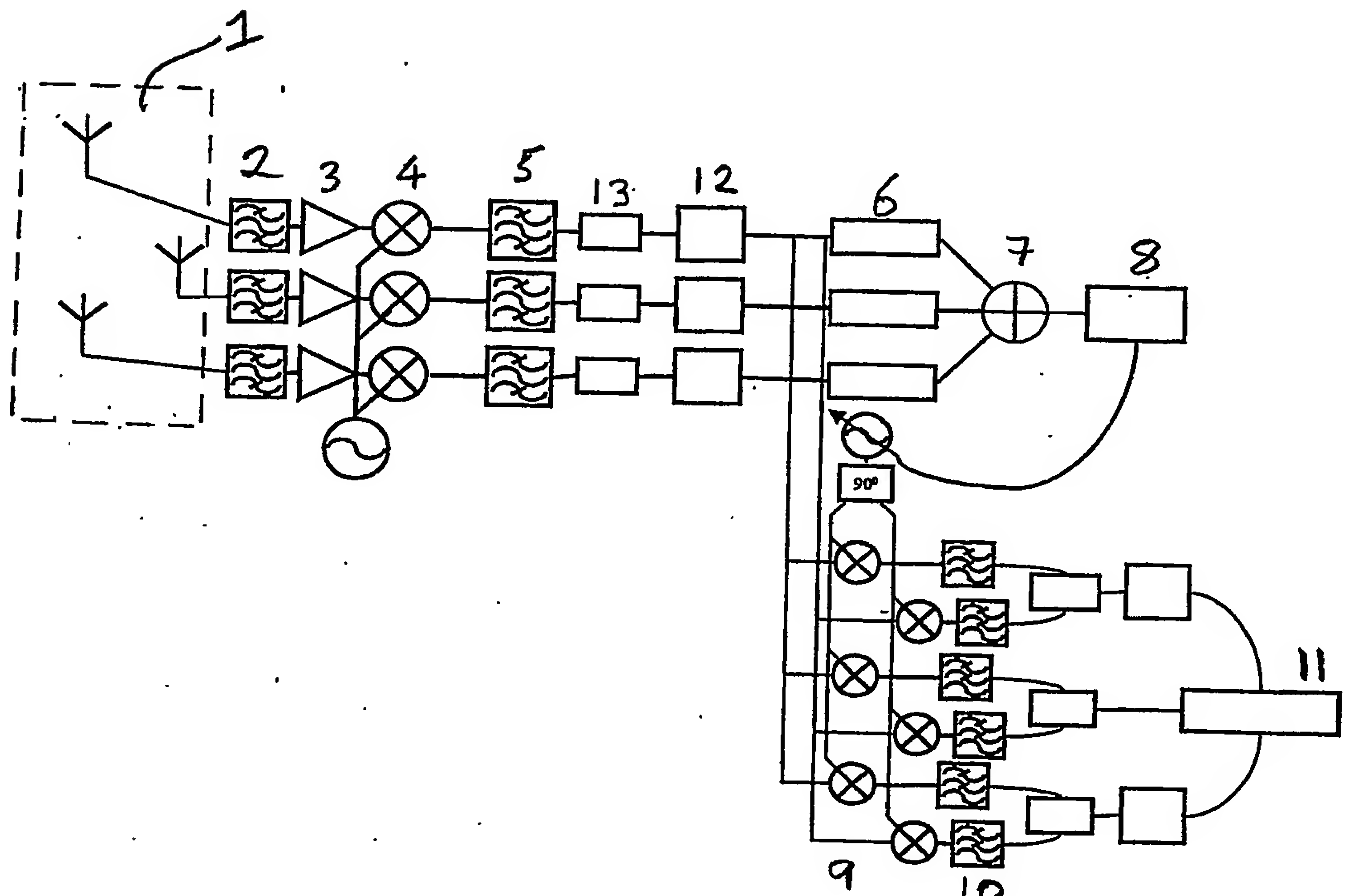

Figure 2

Radio Signal Direction Finder

The invention concerns a method and apparatus for determining the direction of a radio signal having a large frequency uncertainty. It has utility in situations where information concerning the transmitted waveform is known, for example in search and rescue operations.

According to the present invention a method of direction finding for radio signals of known modulation comprises the steps of:

receiving the radio signals on an array of at least three antennae to provide a corresponding number of signal channels;

correlating, for each channel, one or more complete modulation cycle of the signal with the next modulation cycle;

summing the correlated signals so obtained;

determining the frequency of the radio signal of interest from the sum of the correlated signals;

mixing the frequency so determined with the uncorrelated channel signals to produce a narrow bandwidth signal commensurate with the modulation of the radio signals and

applying phase detection and direction finding routines to the narrow bandwidth signals.

A preferred embodiment further includes the step of mixing the received signals to an intermediate frequency (IF) suitable for further processing, prior to correlation of the modulation cycles.

According to a second aspect of the invention, apparatus for direction finding for radio signals of known modulation comprises an array of at least three antennae arranged to receive the radio signals of interest and provide a corresponding number of signal channels;

means for correlating, for each channel, one or more complete modulation cycle of the signal with the next modulation cycle;

means for summing the correlated signals so obtained;

means for determining the frequency of the radio signal of interest from the sum of the correlated signals;

means for mixing the frequency so determined with the uncorrelated channel signals to produce a narrow bandwidth signal commensurate with the modulation of the radio signals and

processing means for applying phase detection and direction finding routines to the narrow bandwidth signals.

In a preferred embodiment, said apparatus further including means for mixing the received signals to an intermediate frequency (IF) suitable for further processing, prior to correlation of the modulation cycles.

The apparatus of the invention works in two phases: first frequency detection and then angle of arrival determination. In the frequency detection phase, additional sensitivity is obtained, compared to a conventional directional receiver, by using the outputs of all the receiving antennas combined in a certain way, but without the associated increased directivity of the larger aperture. Increased directivity is undesirable since this would require the antenna array to be scanned to cover 360°. By the present invention, so long as the noise in each channel is uncorrelated, defined increases in sensitivity may be obtained via coherent addition, by increasing the number of antennas and receiving channels. That is for N channels the signal to noise ratio will increase by N. At frequencies where atmospheric noise is low, that is at VHF and above, the noise in each channel will be largely uncorrelated, since each channel will

posses separate noise sources from lossy and active devices which will dominate over the common atmospheric noise.

The invention will now be described with reference to the following figures in which:

figure 1 shows a schematic representation of a three-channel implementation of the invention and

figure 2 shows another representation disclosing greater detail of how direction of the signal might be determined from the processed data.

Referring to figure 1, signal incident upon an antenna array 1 is passed through filters 2 to remove out of band interference and noise, and also to reject the image frequency caused by the mixing stage.

The signal is then amplified by a low noise amplifier (LNA) 3 and mixed to a suitable lower intermediate frequency (IF) at mixer 4 to facilitate further processing. Additional filters 5 reduce unwanted mixing products.

Correlators 6 correlate one complete modulation cycle with the next to effectively remove the phase information present between the channels. The correlated signals are then summed at 7 (thus realising coherent signal to noise gain) before conventional detection routines, familiar to a person skilled in the art, are applied at processing means 8 to detect the signal of interest in the frequency domain.

Once the exact frequency of the signal of interest has been determined this information is used to slave a local oscillator 9 to force the signals to appear within the bandwidth of the next filters 10 which further reject noise and interference. These filters are set to the bandwidth of the modulation which is known *a priory.* Conventional phase detection and direction finding routines are then applied to the resulting signals at processing means 11.

Referring to figure 2, The down-conversion and band selection circuits convert the received RF signal to a suitable IF where correlation can take place. The First IF is necessarily removed from the final IF in frequency to enable rejection by final IF filters. The bandwidth is that of the full uncertainty bandwidth of the signal. Once frequency detection has taken place, the bandwidth is suitably narrowed to that of the

modulation, thus removing noise from the phase detection and direction finding algorithms.

Where the uncertainty bandwidth allows digital techniques are conveniently used for all the detection processing. This greatly reduces channel to channel variation and allows convenient calibration. To calibrate the system a known signal is fed into the antennas and the scale and phase adjusted accordingly 12.

Angular information is extracted using I and Q processing and the arctan function as shown in figure 2. Other phase detectors could be used however I and Q processing removes the amplitude dependency of the result and therefore eliminates the requirement for an ALC system.

The frequency detection block is based upon the FFT and as such will not present the exact frequency of the input. Thus the output of the arctan function will contain two components: the phase of the wanted signal compared to the A/D clock 13 and a linear ramp of phase due to the detected frequency not being exact. However the difference of the arctan outputs gives the required angle and the linear ramp cancels since it is common.

Claims

1. A method of direction finding for radio signals of known modulation comprising the steps of:

receiving the radio signals on an array of at least three antennae to provide a corresponding number of signal channels;

correlating, for each channel, one or more complete modulation cycle of the signal with the next modulation cycle;

summing the correlated signals so obtained;

determining the frequency of the radio signal of interest from the sum of the correlated signals;

mixing the frequency so determined with the uncorrelated channel signals to produce a narrow bandwidth signal commensurate with the modulation of the radio signals and

applying phase detection and direction finding routines to the narrow bandwidth signals.

2. The method of claim 1, further including the step of mixing the received signals to an intermediate frequency (IF) suitable for further processing, prior to correlation of the modulation cycles.

3. Apparatus for direction finding for radio signals of known modulation comprising an array of at least three antennae arranged to receive the radio signals of interest and provide a corresponding number of signal channels;

means for correlating, for each channel, one or more complete modulation cycle of the signal with the next modulation cycle;

means for summing the correlated signals so obtained;

means for determining the frequency of the radio signal of interest from the sum of the correlated signals;

means for mixing the frequency so determined with the uncorrelated channel signals to produce a narrow bandwidth signal commensurate with the modulation of the radio signals and

processing means for applying phase detection and direction finding routines to the narrow bandwidth signals.

4. The apparatus of claim 3, further including means for mixing the received signals to an intermediate frequency (IF) suitable for further processing, prior to correlation of the modulation cycles.

Abstract

A direction finding radio receiver using an array of receiving antennas for known signals with a relatively large frequency uncertainty is described. Additional sensitivity is obtained, compared to a conventional directional receiver, by using the outputs of all the receiving antennas combined to provide coherent signal to noise gain, but without the associated increased directivity of the larger aperture.